U.S. Army Toxic Metal Reduction Program: Demonstrating Alternatives to Hexavalent Chromium and Cadmium in Surface Finishing

For ASETSDefense

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Support to HQ, RDECOM EALSP

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Environmental Acquisition & Logistics Sustainment Program Elements

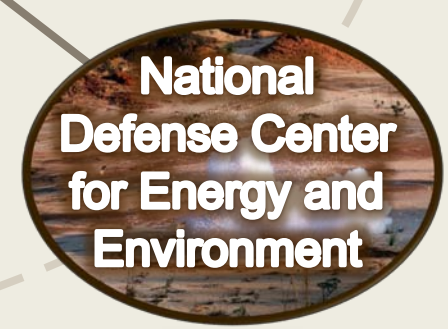
- ORDNANCE ENVIRONMENTAL PROGRAM
- TOXIC METAL REDUCTION
- AIRBORNE LEAD REDUCTION
- ZERO FOOTPRINT CAMP

- STRATEGIC ENVIRONMENTAL RESEARCH AND DEVELOPMENT PROGRAM
- ENVIRONMENTAL SECURITY TECHNOLOGY CERTIFICATION PROGRAM
- JOINT INSENSITIVE MUNITIONS TECHNOLOGY PROGRAM
- JOINT SERVICE SOLVENT SUBSTITUTIONS

- PROTECTIVE COATING DEVELOPMENT
- MATERIAL DURABILITY TESTING
- NON-METALS RESEARCH

- DEFENSE SAFETY OVERSIGHT COUNCIL
- VOLUNTARY PROTECTION PROGRAMS
- NET ZERO INSTALLATIONS

- RDT&E MATRIX SUPPORT
- ENVIRONMENTAL RISK MANAGEMENT
- SUPPORT TO PEOS/PMS
- OZONE DEPLETING CHEMICALS
- GREENHOUSE GASES



Toxic Metal Reduction in Surface Finishing Processes

Purpose: Reduce/eliminate toxic, carcinogenic metals (e.g., hexavalent chromium (Cr(VI)), cadmium (Cd)) in Army metal plating, surface finishing

Addresses: High priority Army Environmental Requirements and Technology Assessment (AERTA) PP-2-02-04, OSD memo and DFARS clause

7:1 Return on investment

15K lbs/yr chromic acid (3 depots)

75% reduction in Cr(VI) used in electroplating
100% of Cr(VI) used in pretreatments
75% reduction in Cd associated with Cr(VI) finishes
Reduction in toxic materials/waste (e.g., cyanide, phosphate sludge)

The Long and Winding Road

FY07: Identified as high priority Pollution Prevention (P2) requirement

FY08-14: Discretionary funding to initiate program

FY10: NDCEE Toxic Metal Impacts Survey

FY12: AMCOM G-4 detailed assessment of hazardous materials utilized in Army depot plating shops

- Requirements
- Alternative Technology Assessments
- Technology Gaps

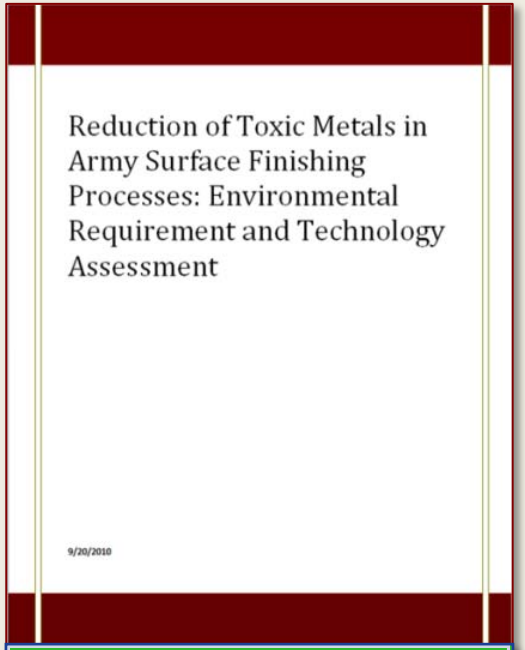
FY13: TMR approved as critical, valid funding requirement

FY14: Program Build

- Projects must “buy-out” process completely
- Technology Transition Agreements in coordination

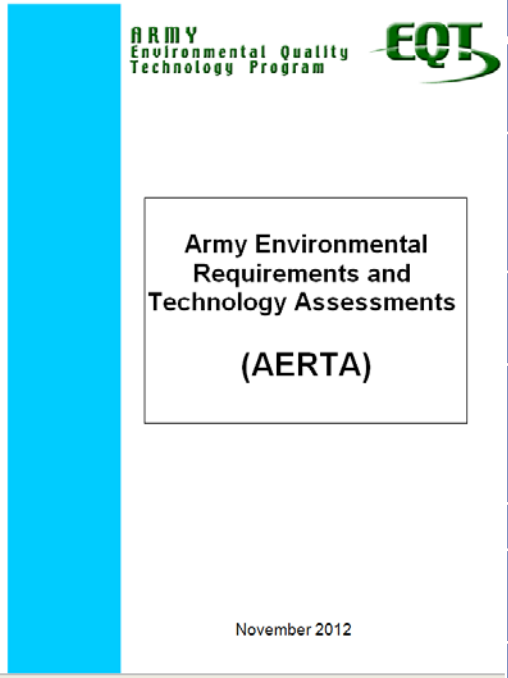
FY15: Demonstration projects initiated

- October: 1st TTA signed by PEO Aviation, CCAD



Hazardous Plating Shop Processes
Chromic acid anodizing of aluminum*
Aluminum conversion coatings*
Hard chrome plating*
Magnesium anodizing*
Sealers and rinses*
Stripping of anodizing and platings*
Passivation of stainless steel*
Cad Plating
Nickel Plating
Electroless Nickel
Etching
*Contains Cr6+

What is the requirement?



#2 P2TT priority (2013)

Process	Specification	Hazardous Chemicals
Aluminum Conversion Coating	MIL-C-5541-E MIL-DTL-81706B	Sodium Dichromate
Aluminum Anodize	MIL-A-8625F Type I and IB	Chromic Acid, Sodium Dichromate, Chromium Trioxide
Cadmium Brush Plate	MIL-STD-865C	Cadmium Special, Cadmium Alkaline, Cadmium Acid
Cadmium Plating	SAE AMS-QQ-P-416B Type II	Cadmium Oxide, Sodium Cyanide, Cadmium, Nickel Chloride, Iridite
Hard Chrome Plate	SAE AMS-QQ-C-320	Chromic Acid
Copper Plating	ASTM 2418F	Copper Cyanide, Sodium Cyanide, Sodium Dichromate
Electroless Nickel	AMS2404F	Nickel Chloride
Magnesium Anodize - Conversion Coating	AMS-M-3171 Type III, IV, VI	Chromic Acid, Sodium Dichromate
Nickel Plating	SAE AMS QQ-N-290	Nickel Chloride, Nickel Sulfate, Nickel Sulfamate
Passivate	SAE AMS 2700B	Sodium Dichromate
Phosphate	MIL-DTL-16232G TT-C-490, Type I	Chromium Trioxide, Chromic Acid
Silver Plating	ASTM B700-97	Potassium Cyanide, Silver Cyanide
Wash Primer	DOD-P-15328 TT-C-490F	Zinc chromate

FY15-19 Planned TMR Projects

Start	Project Title
FY12/FY15	Cr(VI)-Free, Low VOC Alternatives for Spray-In-Place, Mixed Metal Pretreatment
FY13/FY15	Cr(VI)-Free Surface Activation and Preparation for Metal Plating
FY14	Cr(VI)-Free Hard Chrome Electroplating
FY14	Cr(VI)-Free Conversion Coatings
FY15	Cr(VI)-Free Aluminum Anodizing
FY15	Cyanide-Free Copper and Silver Electroplating
FY15	Toxicity Assessments and Testing of Alternative Materials and Processes
	Cold Spray - Large Caliber Gun Barrel Coatings and Donor Tubes
	Cold Spray - Portable System and Internal Diameter Applications
	Citric Acid Passivation
	Cadmium-Free Connectors and Fasteners
	Cadmium-Free Plating for Components
	Dichromate-Free Sealers / Primers
	Cr(VI)-Free Sealants and Adhesives

Cr(VI)-Free Low VOC Alternatives for Spray-in-Place, Mixed Metal Pretreatments, TMR 12-01

- **Objective:** Eliminate Cr(VI) in multi-metal spray-on pretreatment applications (alternative to wash primer)
- **Magnitude of impact:**
  - Reduce Cr(VI) by 24K lbs/year, VOCs by 2.4M lbs/year
  - Potential violation of volatile organic compounds (VOCs) emission limits could restrict maintenance activities
  - Eventual cancellation of DOD-P-15328 technology gap
- **Intended end product:** Validated Cr(VI) spray applied chemical pretreatments for multi-metal applications per TT-C-490F
- **Technology:**
  - Commercially available metal pretreatment technologies on multiple substrates and mixed metal assemblies
    1. Zircobond 4200 (zirconium immersion chemistry)
    2. Oxsilan 9810/2 (organo-silane polymers)
    3. Bonderite (phosphoric acid , hexaflourotitanic acid, Mn)
- **Weapon systems impacted:** All systems currently using DOD-P-15328 chromated wash primer (including MRAP, Stryker, HMMWV, ground support equipment (GSE))
- **Transition Path:** TT-C-490F Qualified Product Database
- **POC:** Jack Kelley, ARL, john.v.kelley8.civ@mail.mil
  - **IPT:** ARL, Letterkenny Army Depot (LEAD), Red River Army Depot, (RRAD), Anniston Army Depot (ANAD), Henkel, PPG

- **FY12** • Laboratory Testing
- **FY13** • Down-selection/Outdoor testing
- **FY14** • Demo at LEAD
- **FY15** • Demo at RRAD and ANAD
- **FY16** • QPD for TT-C-490

Cr(VI)-Free Surface Activation and Preparation for Metal Plating, TMR 13-03

- **Objective:** Eliminate chromic acid (Cr(VI)) used in stripping anodized coatings from aluminum
- **Magnitude of impact:**
  - Eliminate 1,400 lbs/year of chromic acid at Corpus Christi Army Depot (CCAD) in anodize stripping processes
- **Intended end product:** Validated Cr(VI) free chemical stripper for anodized coating on aluminum (Type I, Type III and alternative processes)
- **Technology:** Commercially available chemical strippers
  - NaOH Stripper/Deoxider
  - LNC Deoxidizer (ferric sulfate, nitric acid, HF)
  - Sikorsky (proprietary)
  - Stripol ANO
  - Metalast ADS 1000 (sulfuric acid)
- **Weapon systems impacted:** All systems that use anodized aluminum, including ground tactical and support equipment and aviation systems
- **Transition Path:** Revision to MIL-A-8625
- **POC:** Jack Kelley, ARL, john.v.kelley8.civ@mail.mil
  - **IPT:** ARL, AMCOM, AMRDEC, ANAD, PEO-Stryker Brigade Combat Team, Hubbard Hall, Henkel, Chemetall, AMZ Manufacturing, PPI Aerospace

FY14
- Develop testing protocol
- Laboratory testing

FY15
- Down-select

FY16
- Demonstration at ANAD/CCAD

FY17
- Specification revisions

Cr(VI)-Free Hard Chrome Electroplating, TMR 14-01

- **Objective:** Eliminate Cr(VI) from electroplated hard chrome (EHC) processes
- **Magnitude of impact:**
  - Eliminate 5 tons of chromic acid used in in EHC in Army depot operations (ANAD, CCAD, Rock Island Arsenal)
- **Intended end product:** Cr(VI)-free Non-Line of Sight (NLOS) plating process that results in a hard chrome plate that meets AMS 2460 performance requirements
- **Technology:** Faraday Technologies developed process
  - Trivalent chromium (Cr(III)) bath chemistry
  - Pulsed, reverse waveform rectifiers/power supply
  - Non-lead anodes
  - Leverage: SBIR for stripping chrome plating
- **Weapon systems impacted:** All aircraft maintained at CCAD (UH-60; AH-64; AH-1; CH-47); M1 tank, Stryker, Howitzer at ANAD; processes at RIA
- **Transition Path:** Individual MEOs, CCAD process standard
- **POC:** Michael Johnson, AMCOM, michael.l.johnson17.ctr@mail.mil
  - **IPT:** AMCOM, AED, ARL, PEO Aviation, Utility Helicopter Project Office, CCAD, Faraday Technologies

FY14	• Laboratory testing (130 gallon)
FY15/16	• Process validation and characterization
FY17	• Establish Pilot Process (400 gallon) • Demonstration at CCAD
FY19	• Implementation

Cr(VI)-Free Conversion Coatings, TMR 14-02

- **Objective:** Eliminate Cr(VI) in conversion coatings (CC)
- **Magnitude of impact:**
  - Eliminate 12K pounds of Cr(VI) in Al CC
    - LEAD: 20K lbs/year of Cr(VI) CC solution disposal
    - Savings of over $2.4M in chromate waste disposal
  - Consolidated ferrous and non-ferrous pretreatment line
- **Intended end product:** Multiple approved Cr(VI)-free CCs for aircraft and Ground Support Equipment (GSE) (multi-metal and composites), application by spray and immersion
- **Technology:** Assess commercially available Al pretreatments
  - Aviation: CCAD, TASM-G, Corrosion Repair Facility
    - Spray/immersion: Zirconium oxide, rare earth (Ce), silanes
  - GSE (immersion): ANAD, LEAD, Tobyhanna Army Depot
    - Zirconium oxide, rare earth (Cerium) and silanes
  - Leverage: ESTCP (LEAD) and USMC - Albany demos
- **Weapon systems impacted:** All tactical equipment that requires CARC
- **Transition Path:** TT-C-490, MIL-DTL-53072, MIL-DTL-5541, MIL-DTL-81706
- **POC:** Fred Lafferman, ARL, fred.lafferman.civ@mail.mil
  - **IPT:** AMCOM, AMRDEC, AED, TACOM, LEAD, RRAD, CCAD, TASM-G, PPG Ind.

FY14	• Select candidates • Laboratory testing
FY15	• Demo at aviation facility
FY16	• Demo at GSE facilities
FY17	• Observe demonstration
FY19	• Implementation

Cr (VI)-Free Aluminum Anodizing, TMR 15-01

- **Objective:** Eliminate Cr(VI) in aluminum anodizing, stripping and sealing
- **Magnitude of impact:**
  - CCAD anodize and anodize stripping baths use:
    - Anodize: 2300 gallon tank with 1500 lbs. chromic acid, added as needed (500 lbs. added in 2010-2011)
    - Stripping: 1 process line, 2050 lbs of dry chromic acid
  - International regulation impact on supply chain (REACH)
- **Intended end product:** 1) Validated Cr(VI)-free anodizing process in production environment, 2) validated Cr(VI) free chemical stripper for all forms of anodized aluminum
- **Technology:** Two anodize technologies, Cr(VI)-free strippers
  1. Sikorsky: Tartaric Sulfuric Acid Anodizing
  2. NAVAIR: Thin Film Sulfuric Acid Anodizing process
  3. Cr(VI)-free strippers for legacy, alternative anodize (ARL)
- **Weapon systems impacted:** All aircraft maintained at CCAD (UH-60; AH-64; CH-47), including other Service aircraft
- **Transition Path:** CCAD process standard, MIL-A-8625, MEO added to DMWRs
- **POC:** Scott Howison, AMCOM, stephen.s.howison.civ@mail.mil
  - **IPT:** AMCOM, ARL, Sikorsky, AMRDEC-AED, CCAD, UH-60 Project Office (PO), AH-64E Apache PO, CH-47 PO

FY15
- Initiate laboratory testing with Sikorsky

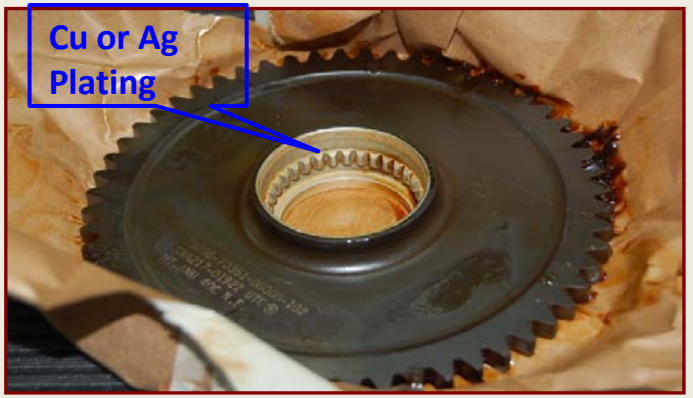
FY16
- Laboratory evaluation of anodic coating stripper

FY17
- Implementation of stripping process

FY19
- Demonstration at CCAD
- Implementation through MEO

Cyanide-Free Copper and Silver Electroplating, TMR 15-02

- **Objective:** Eliminate cyanide from copper and silver electroplating at CCAD
- **Magnitude of impact:**
  - Cyanide alarm requirement: Up to 1 hr evacuation per alarm
  - Cyanide solutions classified as a RCRA waste (F007, F008)
- **Intended end product:**
  - Non-cyanide products and processes for copper and silver plating/strike demonstrated at CCAD
  - Non-chromic acid and non-cyanide stripping methods to remove copper and silver plating/strike demonstrated at CCAD
- **Technology:**
  - Leverage DoD, commercially available plating chemistry
    - E-Brite 30/30 and E-Brite Ultra Cu (Copper)
    - E-Brite 50/50 (Silver), Silver Cyless II
  - Cold spray for LOS Cu or Ag deposition
  - Cyanide, Cr(VI)-free stripping process for copper and silver
- **Transition:** MEOs at CCAD
- **Weapon systems impacted:** All aircraft maintained at CCAD (UH-60; AH-64; AH-1; CH-47)
- **POC:** Sheree York, AMCOM, sheree.t.york.civ@mail.mil
  - **IPT:** AMCOM G-4, CCAD, EPI, AED, ARL, AH-64 PO, UH-60 PO, CH-47 PO



Small Spur Gear, P/N 70351-08088-102

FY15
- Establish Pilot Process at CCAD
- Evaluate CS

FY16
- Demonstrate Plating/Strike
- Laboratory testing

FY17
- Implement Plating/Strike
- Demonstrate Stripping

FY18
- Implement Cr(VI)-Free Stripping

Cold Spray – Large Caliber Gun Barrel Coatings and Donor Tubes, TMR 13-01

- **Objective:** Eliminate Cr(VI) used in plating large and medium caliber bore coatings
- **Magnitude of impact:**
  - Toxic material disposal ~$180k per year
  - Extended barrel life – 2-3x increase in life
- **Intended end product:** Cr(VI)-free, more erosion resistant bore coatings for large & medium caliber guns
- **Technology:**
  - Optimized cold spray (CS) process with tantalum (Ta), tungsten (W) and niobium (Nb) powders
  - Right-angle ID nozzle for direct CS application (large)
  - Additive manufacturing process to produce near-net formed donor tubes for explosive cladding (medium)
- **Weapon systems impacted:**
  - Large Cal: M256 120mm (chamber & bore), M284, M199, & M776 155mm (chambers only)
  - Medium Cal: M242 25mm Bushmaster, M230 30mm, GAU-12 25mm, 30mm Bushmaster II, EAPS 50mm
- **POC:** Vic Champagne, ARL, victor.k.champagne.civ@mail.mil
  - **IPT:** ARL, Benet Laboratories

FY13
- Identify/Develop/Acquire materials
- Develop and design equipment

FY14
- Optimize ID nozzle
- Powder development

FY15
- Execute JTP at Benet for validation
- FY16 Demo Project Plan

Cold Spray – Portable System and Internal Diameter Applications, TMR 13-02

- **Objective:** Eliminate Cr(VI) in electroplated hard chrome
- **Magnitude of impact:**
  - Potential to eliminate Cr(VI) in all Line-of-Sight (LOS) hard chrome applications
  - Increase throughput for dimensional restoration
  - Mobile repair processes
- **Intended end product:** Cr(VI)-free portable CS system for field repair, production process for inner diameter applications
- **Technology:**
  - Portable CS equipment with optimized ID nozzle with amorphous iron, Cr, Ni, and CrC-NiC powders
  - Dimensional restoration of hard (HRC 45+) surface
  - Coordinated path forward for LOS applications
- **Weapon systems impacted:** all LOS hard chrome surfaces (e.g., U-joints for tracked vehicles, M1A1 Sun Gear, HMMWV Ring / Pinion Gears, EMI Shielding for Electronic Shelters)
- **POC:** Vic Champagne, ARL, victor.k.champagne.civ@mail.mil

FY13
- Identify/acquire powders
- Develop Joint Test protocol

FY14
- Characterization
- Laboratory trials

FY15
- Validation on BER parts
- FY16 Demo project plan

Example: Potential Impact of Projects at CCAD Plating Shop (Building 340)

Project	% Cr(VI) Reduction	Start Date (Overall/CCAD)
Cr(VI)-Free Hard Chrome Electroplating	35	FY14/17
Cr (VI)-Free Aluminum Anodizing	13	FY15/17
Cr(VI)-Free Surface Activation and Preparation for Metal Plating	5	FY14/16
Cyanide-Free Copper and Silver Electroplating	2	FY15/15
Cr(VI)-Free Conversion Coatings	7	FY14/16
Tagnite Application for Legacy Components	15	FY14/15
Conversion coating for cadmium plating	7	FYTBD
Black Oxide Sealer (Cr(VI))	2	FYTBD
Passivation and Corrosion Treatment (Cr(VI))	12	FYTBD
Chromated sealant for Phosphate Acid Dip	2	FYTBD
TOTAL Plating Shop	100	

AMCOM G-4 Estimates (2014)

Are the Alternatives More Sustainable?

- U.S. Army Public Health Command will publish Toxicology Assessments for all proposed alternatives
  - Literature review
  - Computational modeling
  - Data collection
  - Toxicity Testing, if necessary
- Data will inform acquisition documentation and occupational exposure requirements
  - Toxicity Clearance, Health Hazard Assessment, PESHE, LCEA
  - Occupational Exposure Limits

Summary

- Army TMR Program will conduct demonstrations of more sustainable surface finishing processes at Army depots, installations from FY15-19
- P2 Technology Team will support transition through document changes, maintenance orders and updates to QPD
- Eliminate 100% of Cr(VI), Cd or toxic constituents in select processes Army-wide
- Seeking leveraging opportunities, data sharing, support for specification changes and promising technologies for future demonstrations